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### **Axial setting device with torque determining means**

#### **Description**

The invention relates to a method of determining the coupling torque in a friction coupling with an electro-mechanical actuator which comprises a supporting element substantially axially fixed in a housing and an axially displaceable setting element supported on said supporting element; the invention also relates to a friction coupling with an electro-mechanical actuator, more particularly for being used in a lockable differential drive or as a hang-on coupling for an optionally drivable driving axis of a motor vehicle, wherein the actuator comprises a supporting disc axially fixed in a housing and a setting disc which is axially supported on said supporting disc. Friction couplings for the range of application mentioned here have torque control purposes, i.e. more particularly they serve to control the distribution of torque at two wheels of a driven axle or between two drivable axles. To be able to carry out suitable control processes, the coupling moment transmitted by the coupling has to be known, i.e. it has to be constantly determined by suitable means. In prior art processes of determining the coupling moment, the values such as speeds, temperatures etc. are measured by sensors, theoretical values (transmission ratios, efficiency etc.) are calculated, and corrected factors (friction coefficients, efficiency, temperature and speed dependencies etc.) as determined by tests are stored; the measured, calculated and interpolated values are evaluated in a computer

or processor unit and the correct current for achieving a calculated coupling moment is set at the electric motor of the actuator. There is thus provided an open loop.

Because of existing non-linearities and deviations in the coupling behaviour and in the behaviour of the actuator, the coupling moment values set in this way and thus the respective torque values at the wheel or axles in some cases greatly deviate from the theoretical physical values. The degree of accuracy achieved in this way for setting the coupling moment is sometimes not sufficient. Storing the required evaluation tables in an ECU or in a processor is complicated and does not allow the complete physical model of the coupling to be copied sufficiently accurately. For evaluating the measured, calculated and interpolated values ECU storage and computer capacity are used and are time-consuming. Several sensors are required for obtaining the required measured values (speed measurements, temperature sensors, etc.).

It is therefore the object of the present invention to propose a process and a friction coupling of the initially mentioned type by means of which the coupling torque can be controlled in a less complicated and more accurate way. The objective is achieved by a process which is characterised in that the supporting element is axially supported in the housing via an undisplaceably enclosed hydraulic medium and that the pressure in the hydraulic medium is measured and used by using value tables for the actuator and the friction coupling for the purpose of calculating the coupling torque in a central ECU. More particularly, it is proposed that the axial force of the actuator is calculated from the measured pressure, using a stored value for the effective face of the supporting element. Furthermore, it is proposed that, by using the stored values for the friction value and for the friction faces of the

coupling, the coupling moment is calculated from the supporting force of the supporting element and the axial force of the actuator respectively.

According to a preferred embodiment, it is proposed that the pressure is controlled in a closed control circuit by setting the actuator to a respective nominal value. This means that instead of an open loop, use is made of a closed loop based on the pressure as the only measured or controlled variable.

In this way, the axial setting force is controlled by a closed loop, and for converting the measured pressure into the axial force, only the effective surface of the supporting disc loaded by a hydraulic medium needs to be known and stored, and for calculating the resulting coupling torque, only the friction values of the coupling plates and the mean coupling diameter need to be known and stored in value tables. On the basis of these, the coupling torque required for a certain driving condition is converted by the Electronic Control Unit (ECU) into the nominal value for the axial force of the actuator and the pressure respectively and directly compared with the signal of the pressure sensor by controlling the actuator. The torque calculated on the basis of the axial force can be made available on the vehicle CAN bus.

According to a first solution, the inventive friction coupling is characterised in that the supporting disc is provided in the form of an annular piston in an annular chamber filled with a hydraulic medium and that, in the housing, there is arranged a pressure sensor element for measuring the hydraulic pressure in the annular chamber. It is proposed that the pressure sensor element is connected to a branch line leading to the annular chamber, or the pressure sensor element can be directly introduced into the annular chamber.

An alternative inventive friction coupling is characterised according to a second solution in that the supporting disc is provided in the form of an annular plunger and that into the housing there is inserted an annular housing with a cover, which annular housing and cover form an annular chamber which is filled with a hydraulic medium and in which there is arranged a pressure sensor element for measuring the hydraulic pressure in the annular chamber, wherein the annular plunger acts on the cover. It is possible for the cover to be provided in the form of a flexible diaphragm closing the annular housing. Alternatively, it is possible for the cover to be displaceable in the annular housing and to be sealed relative to the annular chamber.

In any case, the hydraulic medium can be freely selected. However, to avoid any leakages, it is proposed to use a hydraulic medium with a high viscosity, e.g. an oil or gel. For sealing, preference is given to annular seals, but these can be eliminated if the hydraulic medium is formed by an elastic, self-supporting formed member.

Preferred embodiments of the invention are illustrated in the drawings and will be described below.

Figure 1 shows a first embodiment of a multi-plate coupling with an electro-mechanical actuator with hydraulic support.

Figure 2 shows a second embodiment of a multi-plate coupling with an electro-mechanical actuator with hydraulic support.

Figure 3 shows a third embodiment of a multi-plate coupling with an electro-mechanical actuator with hydraulic support.

Figure 4 shows the pressure recording element according to Figure 3 in an enlarged form.

Figure 5 shows a fourth embodiment of a multi-plate coupling with an electro-mechanical actuator with hydraulic support.

Figures 1 to 3 will initially be described jointly to the extent that the identifiable details correspond to one another. A shaft 14 connected to a multi-plate coupling 15 is supported in a multi-part housing 11 via a ball bearing 12 and an axial bearing 13. The shaft 14 is produced so as to be integral with a hub 16 of the multi-plate coupling, whereas a coupling carrier 17 of the multi-plate coupling is integrally connected to a further hub 19. The shaft 14 comprises a flange 18 for connecting a first shaft suitable for being flanged on; the second hub 19 comprises a shaft toothing 20 for attaching a second shaft suitable for being plugged in. The multi-plate coupling comprises first coupling plates 22 connected to the hub 16 in a rotationally fast way and second coupling plates 23 which are connected to the carrier 17 and which are arranged so as to alternate in the axial direction. The package consisting of first and second coupling plates 22, 23 is supported on a supporting plate 24 secured to the hub 16 and can be axially loaded by a pressure plate 25 which is axially displaceable relative to the hub 16. Between the coupling plates 22, 23 and the pressure plate 25 there is arranged a pair of plate springs 26, 27 for returning the pressure plate. The pressure plate 25, in turn, is displaced via an axial bearing 28 by an axial setting device 29 which can be driven by an electric motor 30. The drive is effected from the shaft 31 of the electric motor via a reduction stage 32 to the axial setting device 29.

In the embodiment as illustrated, the axial setting device (actuator) consists of a pressure or setting disc 34 rotatably drivable via a tooth segment 33, and of an axially supported supporting disc 35 held in the housing 11 in a rotationally fast way. On their end faces facing one another, the discs 34, 35 comprise ball grooves 42, 43 for balls 45 guided in a cage 44. The ball grooves are arranged in pairs and extend in the circumferential direction, and they comprise gradients extending in opposite directions and variations in depth. When the disc 34 is rotatably driven relative to the axially supported and rotationally secured disc 35, the balls run from deeper ball groove regions to shallower ball groove regions, as a result of which the disc 34 moves away from the disc 35 towards the multi-plate coupling. The coupling package is closed. When the drive rotates in the opposite direction or when the electric motor 30 is current-less, the returning force of the plate springs 26, 27 causes the disc 34 to be pressed back and, under the effect of the balls 45 in the ball grooves 42, 43, it is rotated back.

In the embodiment according to Figure 1, the supporting disc 35 is provided in the form of an annular piston which is held, so as to be axially free and rotationally secured, in an annular cylindrical chamber 36 filled with a hydraulic medium. The disc 35 is sealed relative to the chamber 36 by sealing rings 52, 53 positioned on the piston face. From the chamber 36 there starts a radial bore 37 which is closed by a threaded plug 38. A transverse bore 39 passing through the radial bore 37 is connected to a pressure sensor element 40 having integrated sensor electronics. The chamber 36, the radial bore 37 and the transverse bore 39 are completely filled with a hydraulic medium, so that the disc is axially firmly supported mainly by the hydraulic medium. The pressure sensor 40 measures the pressure in the cylindrical chamber 36 and, via a

cable 41, transmits the measured values to an ECU in which the measured pressure is converted in the initially described way into the actually transmissible coupling moment.

Figure 2 shows the supporting disc 35 in the form of an annular piston which is held, so as to be axially free and rotationally secured, in an annular cylindrical chamber 36 which is filled with the hydraulic medium. The disc 35 is sealed relative to the chamber 36 by sealing rings 52', 53' arranged in the chamber 36. A pressure sensor element 60 introduced into the housing is arranged in the chamber 36. The pressure sensor element records the pressure in the cylindrical chamber 36 and transmits a pressure signal into a pressure sensor electronic system (ECU) 62 which is arranged at the housing and in which, in the initially described way, the measured pressure is converted into the actual coupling moment, with the calculated value, via a bus of the motor vehicle, being made available for further use.

In Figure 3, the supporting disc 35 is provided in the form of an annular piston which, so as to be axially free and rotationally secured, is held in an annular cylindrical chamber 36 into which an annular housing 51 filled with a hydraulic medium is inserted without any play. In this embodiment, the disc 35 does not have to be sealed relative to the chamber 36. A pressure sensor element 60 introduced into the housing is arranged in the annular housing 51. The pressure sensor element records the pressure in the annular housing 51 and transmits a pressure signal into a pressure sensor electronic system (ECU) 62 which is arranged at the housing and in which, in the initially described way, the measured pressure is converted into the actual coupling torque.

In Figure 4, the annular housing 51 according to Figure 3 is shown in an enlarged form as a detail. It is possible to see an annular housing 51 at whose inner circumference and outer circumference there have been inserted seals 52", 53". At one end face, there is inserted a flat annular cover 54 which is sealingly held by two beadings 55, 56 relative to the seals 52", 53". The annular housing 51 is completely filled with a hydraulic medium. At one circumferential place of the housing 51, there is inserted a pressure sensor element 60 whose attaching end is guided out of the housing through a bore 61. The cover 54 is provided in the form of an elastic diaphragm or in the form of a displaceable cover which is permanently sealed by the seals 52, 53 and which is axially acted upon by the supporting disc.

In Figure 5, the supporting disc 35 is provided in the form of an annular piston 35 which, in an axially free and rotationally fastened way, is held in an annular chamber 36 filled with a hydraulic medium. The consistency of the hydraulic medium is such that the disc 35 does not have to be sealed relative to the chamber 36. For instance, the hydraulic medium can be provided in the form of a two-component gel which is filled into the chamber in a liquid form and then gels. Alternatively, the hydraulic medium can consist of a prefabricated formed member, e.g. a silicone disc. In this case, too, a pressure sensor element 60 is introduced into the chamber 36, which records the pressure in the cylindrical chamber 36 and transmits a pressure signal to a pressure sensor electronic system mounted on the housing 11. For the rest, reference is made to the previous embodiments.



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List of reference numbers

- |    |                                 |
|----|---------------------------------|
| 11 | housing                         |
| 12 | ball bearing                    |
| 13 | axial bearing                   |
| 14 | shaft                           |
| 15 | multi-plate coupling            |
| 16 | coupling hub                    |
| 17 | coupling carrier                |
| 18 | flange                          |
| 19 | hub                             |
| 20 | shaft assembly                  |
| 21 | -                               |
| 22 | coupling plates                 |
| 23 | coupling plates                 |
| 24 | supporting plate                |
| 25 | pressure plate                  |
| 26 | plate spring                    |
| 27 | plate spring                    |
| 28 | axial bearing                   |
| 29 | axial setting device (actuator) |
| 30 | electric motor                  |
| 31 | shaft                           |
| 32 | reduction stage                 |
| 33 | tooth segment                   |
| 34 | setting disc                    |
| 35 | supporting disc                 |
| 36 | annular cylinder                |

37	radial bore
38	plug
39	transverse bore
40	pressure sensor element with integrated electronic system
41	cable
42	ball groove
43	ball groove
44	cage
45	ball
51	annular housing
52	seal
53	seal
54	cover
55	beading
56	beading
60	pressure sensor element
61	bore
62	pressure sensor electronic system